THE BALSAM WOOLLY APHID PROBLEM IN OREGON AND WASHINGTON

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IN
OREGON AND WASHINGTON

By

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Frontispiece

A branch of subalpine fir heavily "gouted" by the balsam woolly aphid. Terminal buds are dead and no new foliage is being produced.

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SUMMARY

A European insect, commonly called the balsam woolly aphid or chermes, is damaging and killing true fir (*Abies*) in western Oregon and Washington. Some 350,000 acres are known to be infested. Tree killing has reached the point where concerted action is needed. Major salvage plans are being developed by private, state, and federal forest managers to utilize as much of the dead and dying timber as possible. Studies of the insect and means of controlling it are underway and are being expanded.

The balsam woolly aphid is a tiny insect less than one-sixteenth inch long that damages and kills trees by feeding on the twigs, branches, and bole. It is a serious enemy of many species of *Abies* in various parts of the world. The first record of the balsam woolly aphid in North America is from Maine in 1908. It was found in the Pacific Northwest shortly after 1930 infesting grand fir (*Abies grandis*). In 1954 it was discovered in epidemic numbers on Pacific silver fir (*A. amabilis*) in southwest Washington, and on subalpine fir (*A. lasiocarpa*) near Mount Hood, Ore.

The most serious infestation at present is in Pacific silver fir stands near Mount St. Helens in southwest Washington where sawtimber over extensive areas is being killed. Smaller infestations of silver fir are present in the Washington and Oregon coast ranges. Widespread killing of subalpine fir is occurring in several major watersheds of the Cascade Range, particularly in the Mount Hood area of Oregon. Grand fir is attacked in various parts of the region. Infestations of all species combined now extend from the vicinity of Mount Rainier, Wash., to the Crater Lake area in Oregon, a distance of about 250 miles.

The actual volume of timber killed has not been determined but many million board feet of silver fir are dead in the Mount St. Helens area alone. Damage to watersheds from wholesale killing of low-value and non-merchantable alpine species is also yet to be determined. The balsam woolly aphid is creating numerous forest management problems, such as: (1) How to reach inaccessible infested stands, (2) how to adjust sustained yield cutting plans to accommodate the emergency salvage, (3) how to provide protection against the increased fire hazard from scattered salvage-logging slash and countless snags, and (4) what future timber crop to encourage on areas now growing true fir. Sizeable salvage programs are already under way in some heavily damaged sawtimber stands, and additional emergency measures are being developed to utilize the tremendous volume of dead and dying true fir and intermingled species. Because true fir deteriorates very rapidly, greatly expanded salvage is needed. At present no practical control of the insect is known.

The balsam woolly aphid is regarded as a serious threat to all true fir forests of Oregon and Washington. Its destructiveness has been alarmingly demonstrated on three western species of *Abies*. This insect is expected to be a major problem for forest managers and research foresters for many years to come.

INTRODUCTION

The balsam woolly aphid (Adelges piceae Ratz.), a tiny European insect also commonly called "chermes", is currently causing widespread damage and mortality to true firs (Abies) in western Washington and Oregon. The purpose of the following paper is (1) to report the seriousness of the problem, (2) to discuss what is being done and what should be done about it, and (3) to describe the insect and its habits so that foresters will be better able to recognize it.

Research on the chermes problem in the Pacific Northwest has been largely observational and exploratory since discovery of the outbreak in 1954; accordingly, knowledge is incomplete. Much is known, however, about the insect in other parts of the world; this information has recently been summarized by Rudinsky (12) especially for use in the Northwest. In the present paper the authors have combined knowledge from other countries with findings from their own independent but coordinated research; they have shared equally in its preparation.

THE CURRENT OUTBREAK

Areas and Species Affected

The most serious epidemic is in Pacific silver fir (Abies amabilis (Dougl.) Forbes) stands in the Cascade Range of southern Washington (Figure 1). It is especially severe in stands of large sawtimber in the upper Toutle, Lewis and Green River drainages near Mount St. Helens (Plate I). Other infestations in Washington in Pacific silver fir and subalpine fir (Abies lasiocarpa (Hopk.) Nutt.) have been found as far north in the Cascades as Mount Rainier. Infestations have also been found in Pacific silver fir in the Washington Coast Range in Pacific County, and in grand fir (Abies grandis (Dougl.) Lindl.) in the Kelso-Longview area. Total acreage infested in Washington as determined by aerial surveys in 1956 is slightly more than 200 thousand.

In Oregon some 150 thousand acres are infested, principally in subalpine fir and Pacific silver fir stands in the northern Cascade Range near Mount Hood. Spot infestations extend southward along the Cascades almost to Crater Lake National Park. A nearly pure stand of large Pacific silver fir sawtimber in the Oregon Coast Range in Polk and Lincoln Counties is very heavily infested. Grand fir along the lower Willamette River is also attacked.

Several introduced host species, including European silver fir (*Abies alba* Miller), Fraser fir (*A. fraseri* Pursh. Poir) and corkbark fir (*A. lasiocarpa* var. *arizonica* (Merriam) Lemm.) have been attacked and a number of trees killed in the Wind River Arboretum in Washington.

So far, noble fir (*Abies procera* Rehd.) and Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.) appear to have at least some degree of resistance to attack in Oregon and Washington, even when growing immediately adjacent to infested species. Only a few infested noble fir have been found, and no Shasta red. Annand (1) and Varty (15), however, report aggressive infestations on noble fir in California and Europe, respectively. It will be important to determine if these species are truly resistant in the Northwest or if they have merely escaped attack by chance.

Spread of the infestation since its discovery in 1954 has been rapid. The following table shows infested acreages in the Pacific Northwest as determined from aerial surveys and ground checking (16).

Year	Total (Acres)
1954	276,000
1955	295,000
1956	356,000

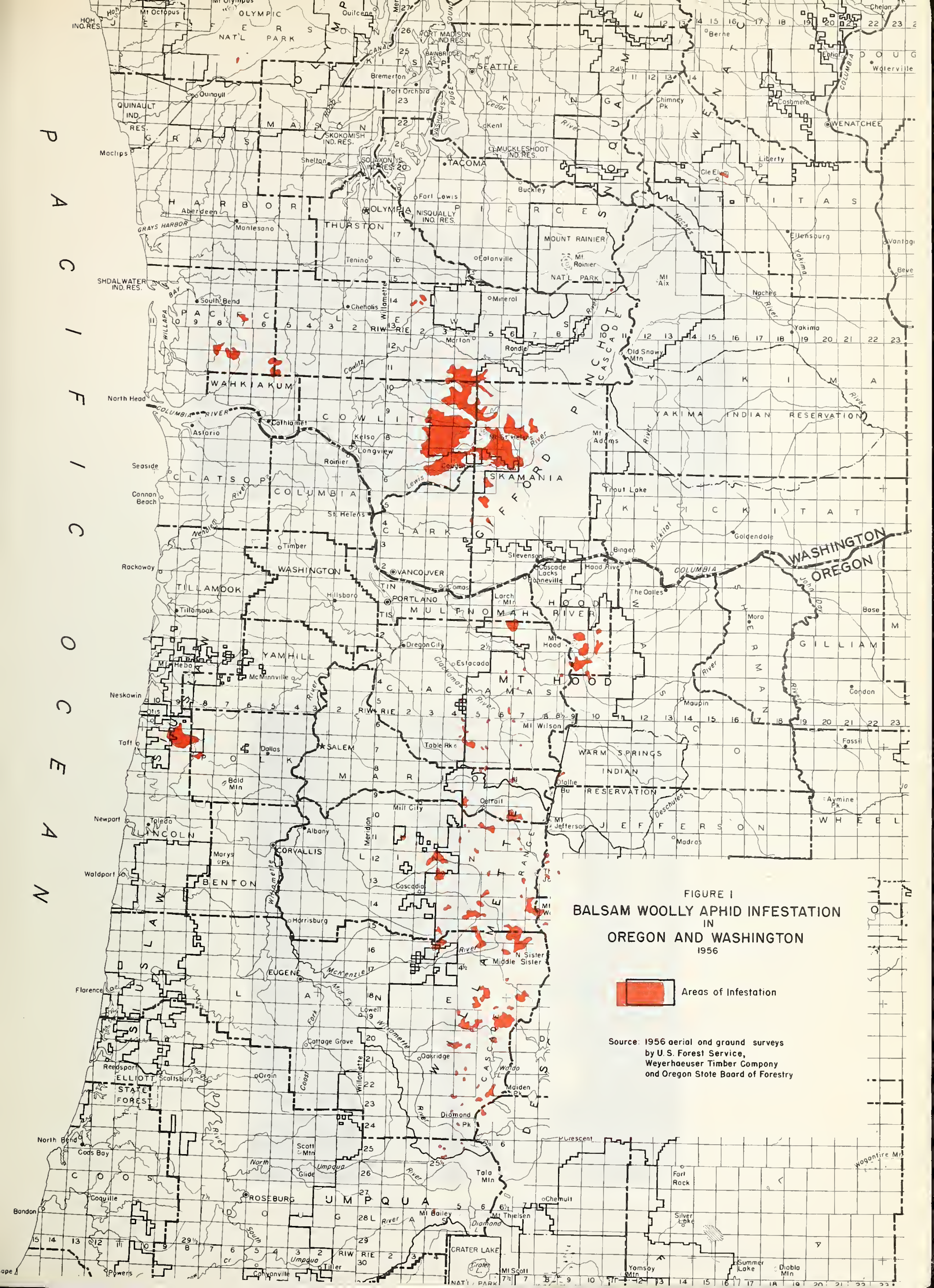


FIGURE I
BALSAM WOOLLY APHID INFESTATION IN OREGON AND WASHINGTON
1956

Plate I

BALSAM WOOLLY APHID DAMAGE

Figure 1. Heavily damaged Pacific silver fir stand on Weyerhaeuser Timber Company tree farm near Mt. St. Helens, Washington.

Figure 2. Dead and dying Pacific silver fir on Gifford Pinchot National Forest, Washington.

Economic Importance

Effects of the epidemic on the economy of the region already are serious. Pacific silver fir, the third most important tree in timber volume in the state of Washington, is the principal pulp producing species in many areas. Most of the infested subalpine fir is below sawtimber size, but is highly important as watershed cover and potentially valuable for pulp and other special uses. Grand fir is a widely distributed and important pulp and timber tree in the two states.

Thousands of acres of dead and dying timber attest to the importance of the outbreak. No detailed assessment of the volume of timber killed to date has been made, although it is known that many million board feet have been killed in the upper Toutle and Lewis River drainages of Washington alone. Rudinsky (11) reports that 50 to 70 percent of the trees in some stands in this area have been killed. Much of this area is within the boundaries of the Gifford Pinchot National Forest, where plans for a 10-year salvage program have recently been completed. The program calls for harvesting an estimated 3/4 billion board feet of chermes-affected true fir and 1-1/4 billion board feet of intermingled species. It is estimated that the timber scheduled for cutting due to the chermes outbreak has a stumpage value of approximately 50 million dollars. To remove the timber, some 275 miles of access roads, costing an estimated $9,160,000 will be needed. Removal of the timber will greatly exceed the allowable cut of the area and necessitate change in existing long-term management plans. Private and state holdings adjacent to the National Forest are faced with the same problem and have similar action programs under way or planned.

In appraising the economic importance of the insect in this region, recognition should be given to experience with it in other parts of North America. In eastern Canada and the New England States it ranks near the spruce budworm in destruction to balsam fir, the most important pulp species of these areas (2), (5), (9). Much effort is expended, particularly in Canada, by researchers and forest managers to minimize damage by the insect.

The program which has been started to salvage the great quantities of dead and dying true fir is likely to have a disturbing effect on lumber manufacture and marketing programs. At present, mills are geared to handle a limited amount of salvage timber, particularly true fir. Accordingly, development of new uses for these species or substitution of them for other woods will be necessary. Also, the use of salvage material in various stages of deterioration gives rise to many problems in pulp manufacture. Fluctuations in pulp quality and consistency not only cause problems in the pulp mills; they also cause pulp-using manufacturers, often far removed from the Region to adjust their production techniques and methods.

Effects on Forest Management

The chermes outbreak has created many problems for the forest manager. The problem of salvage is especially complex because the affected trees and stands are intermingled with nonsusceptible tree species and are generally in remote undeveloped areas. Furthermore, the ownership pattern is checker-boarded in many areas, the rate of deterioration is rapid, and breakage of killed true fir when felled is high.

It will no doubt take several years to salvage the timber already dead. This will seriously disrupt management plans. On most ownerships the heavy salvage cutting will mean that sustained yield cutting budgets will be exceeded. In some areas long-term management plans have already been rewritten. Fire hazard in slash from the widespread salvage cuttings is an added problem; as is the possibility of bark beetle epidemics in the chermes-weakened timber.

Since chermes attacks true firs of all ages the question of what tree species to encourage in the next crop is an important one. So far, noble fir (*Abies procera* Rehd.) and Shasta red fir (*Abies magnifica* var. *Shastensis* Lemm.) appear to be at least somewhat resistant to the insect in Oregon and Washington. If noble fir proves to be inherently resistant it offers possibilities for propagation on many areas now occupied by silver fir. Research and testing will be necessary before positive recommendations can be made. In the meantime, large cutovers will be developing as salvage logging progresses, and the problem of what to plant will become increasingly critical.

THE INSECT

History in North America

Entomologists believe chermes was introduced from Europe where it occurs on various *Abies* in Germany, France, Switzerland, Denmark, Britain, Norway, and Sweden. The insect was first recorded in the United States in 1908 at Brunswick, Maine. It is now widely distributed in the New England states and eastern Canada. It was reported from the San Francisco Bay area of California by Annand in 1928 (1), and in the Willamette Valley on grand fir by Keen (8) shortly after 1930. The present outbreak was first discovered near Mount St. Helens, Wash., in 1954; that same year it was found killing subalpine fir extensively in the Cascade Range in Oregon. There is evidence that it had been present in these areas for several years prior to its discovery.

The scientific name of the insect is controversial. Although the specific name *piceae* is generally accepted, the generic name, depending on the part of the world, is referred to as *Chermes*, *Adelges*, or *Dreyfusia*. *Adelges piceae* Ratz, is used by Balch (2) and Varty (15). A closely related and often associated species, *A. nusslini*, has been described in this country by Annand (1), and been identified by the U. S. National Museum from collections made in California and Oregon. It is quite possible that this species is causing some of the damage, particularly on subalpine fir, in Oregon and Washington.

Description

Detailed biological investigations of the insect to date have been made only in Pacific silver fir stands near Mount St. Helens where it has been identified by taxonomists in Canada and at the U. S. National Museum as *Adelges piceae*. The adults of *A. piceae* are soft-bodied, wrinkled insects with short legs and antennae. They are hemispherical in cross section but longer than wide. The body is usually entirely covered with long, waxy threads, hence the name woolly aphid. The mouth parts consist of long stylets or feeding tubes that protrude from between the front legs. The stylets may be several times as long as the insect itself (plate II).

Eggs are about one-half as long as the adult female. They are oblong-oval and light brown when first laid; later they turn somewhat purplish and become covered with a light waxy bloom. The egg skin or chorion is very thin and transparent and fastened to the bark by a thin thread. The eyes of the developing insect are visible within the egg before it hatches.

When first hatched, the nymphs (called neosistens or larvae) are about the size and color of the egg. The body is somewhat flattened and has long antennae and legs which enable it to move about freely. After the nymph has inserted its stylets into the tree, its body turns deep purple or black and becomes regularly fringed with white wax ribbons that arise from pores on the dorsal side. There are two additional instars between the nymphs and adult stages. At each moult the insect becomes larger, more convex, and has proportionately shorter legs and antennae than as a nymph. The production of wax also increases. In addition to these usual forms, two rare forms (progrediens) are reported by Balch (2) and Varty (15). One of these is winged. These rare forms have not been discovered in Washington or Oregon.

Seasonal History

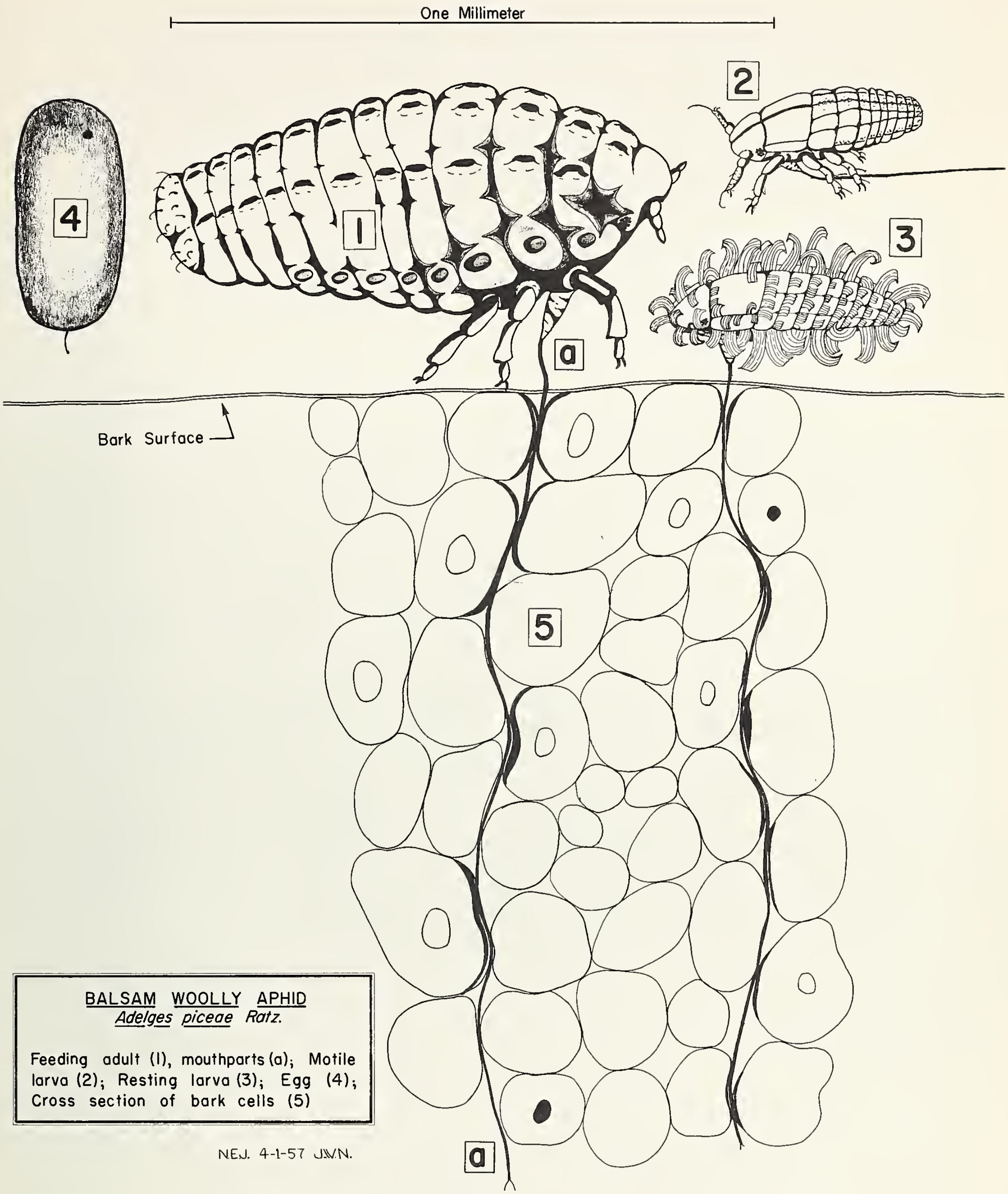
In the Northwest some of the details of the life cycle are yet to be determined; however, the general life cycle as found on Pacific silver fir is known. Adelges piceae on Pacific silver fir in the Mount St. Helens area has two generations per year. The insects of each generation are similar in appearance and habits but are termed summer form (aestivosistens) and winter form (hiemosistens) by most authorities. Populations of A. piceae consist only of females, which lay self-fertile eggs.

In the fall the progeny of the summer form insert their stylets, become fringed with wax ribbons, and hibernate over winter. Activity resumes early in the spring and is first indicated by a swelling of the body and the appearance of a drop of "honeydew" at the posterior end. The insect moults three times and egg laying begins within a few days after the insect has reached the adult stage which may vary from May to July, depending on the elevation.

Incubation period of the eggs is about two weeks and hatching continues through August. The newly hatched nymphs wander about on the bark for some time before inserting their stylets. This so-called summer form then goes into a period of inactivity (diapause) for several weeks. It resumes activity in the same manner as the overwintering form does in early spring, but moulting proceeds somewhat faster. When the adult stage of the summer form is reached, egg laying begins and continues until brought to a gradual halt by low temperatures. The nymphs that hatch from these eggs are the winter form, which insert their stylets into the bark and go into hibernation.

The life cycle of the insect in the Northwest varies somewhat from that in the Northeast and in Europe. The principal differences appear to be the marked overlapping of summer and winter generations and the longer period of seasonal activity in the Northwest. This is probably due to the milder climate here. The number of eggs laid by each adult is also less in the Northwest than that reported in the Northeast and in Europe. Using an average of 100 eggs for the winter form and 50 eggs for the summer form, Balch reports a reproductive potential in eastern Canada of 5000 progeny from 1 adult in a single season (2).

PLATE II



BALSAM WOOLLY APHID
Adelges piceae Ratz.

Feeding adult (1), mouthparts (a); Motile larva (2); Resting larva (3); Egg (4); Cross section of bark cells (5)

Methods of Spread

Spread through the forests of the Pacific Northwest has probably occurred principally through wind dispersal. Eggs and nymphs are often carried for some distance on air currents. Newly hatched nymphs are capable of crawling over the bark before inserting their stylets; Balch (2) reports nymphs moving as much as 100 feet. It is apparent that once the insects reach an uninfested tree, they are capable of spreading to all parts of it in a short time.

The distribution of infested nursery stock has been an important means of spread in Europe, and probably also in this country. Accordingly, nurseries growing *Abies* should be frequently inspected. In Europe, moving of infested logs through aphid-free forests is regarded as a means of dispersal. Birds and small animals may also contribute to spread but their role is probably minor.

Effect on the Host

The balsam woolly aphid damages its hosts by feeding from living tissue immediately beneath the bark surface. The mouthparts of the insect consist of four grooved stylets which when placed together form a sucking tube, several times as long as its body. The insect inserts the tube into the tree by alternately advancing the outside stylets (mandibles) a short distance, then the inner pair of stylets (maxillae). The process is repeated many times until the stylets are advanced into succulent tissue where feeding occurs.

Chermes may attack twigs, limbs, or trunks of trees of all ages. Seedlings as young as two years and trees over six feet in diameter may be infested. Attack by this insect may result in deformity, growth reduction or death.

Attacks on the twigs usually cause contorted swellings, commonly called "gout" (plate III). These swellings may inhibit growth of new foliage to the extent that death of the tree eventually results. Cause of the gout is not completely understood, but most authorities agree that a material in the insect saliva, possibly an enzyme, stimulates the plant into production of enlarged cells in the neighborhood of the inserted stylets.

Plate III

FORMATION OF GOUT

Figure 1. Heavy infestation of chermes nymphs on terminal bud. (X13)

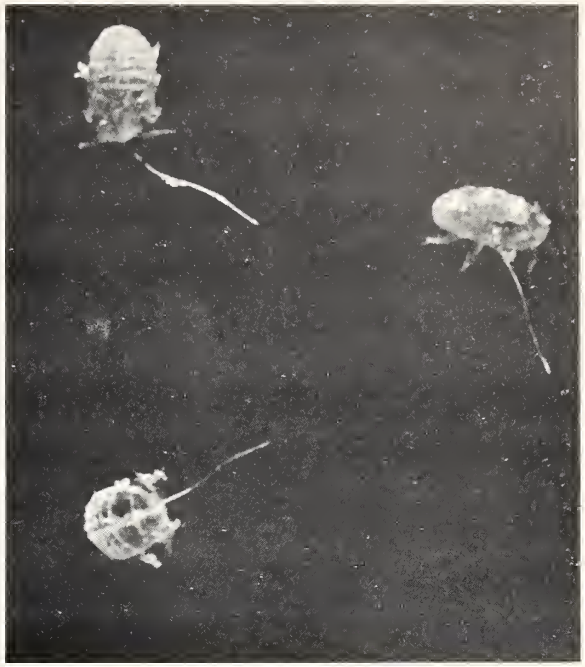


Figure 2. Nymphs removed to show feeding tubes or stylets. (X50)

Figure 3. Gout beginning to form on infested bud. (X4)

Figure 4. Twig terminals gouted and killed by heavy attack. Note especially large swellings around old staminate flower buds.

The gouts or swellings are usually larger in the upper portion of the crown than at the base, although frequently they become so abundant over the entire tree that all the buds are killed and no new foliage develops. Absence of new foliage on heavily gouted trees is most apparent during the spring and early summer when the light green new needles on healthy trees are strikingly evident.

The main stem is also often attacked and takes on a whitish appearance from the secretions of wax or "wool" by the insects (plate IV). In feeding, the insects insert their stylets intercellularly and suck juices from the parenchyma cells of the cortex (plate II). Such feeding, accompanied by the toxic salivary injections, often kills trees in a few years, whereas trees with only a crown infestation may survive for several years. Large areas of dead bark form beneath the areas of insect attack, and a reddish brash wood with thick-walled tracheids and small lumina are characteristic results of a stem infestation. Balch (3) reports that this red wood, or "rotholz" as it is called in Europe, is inferior for lumber or pulp.

Species of Abies differ in their response to chermes attacks. Pacific silver fir trees generally die from the top downward, while grand firs typically die from the lower crown upward. Subalpine fir follows the pattern of silver fir, but dies much more rapidly from heavy attack; apparently for this reason the dead foliage is more brilliantly colored than that of either silver or grand fir.

Despite the variation in response to attack, the three timber species now infested in the Northwest usually show maximum color change (e.g. to red or yellow foliage) in late August or early September. Accordingly, aerial sketch mapping or photographic surveys are best made at this time. At other times of the year, infested and damaged stands have a typically grayish to blackish cast that can be detected under good light conditions. On cloudy overcast days, it may be difficult to detect even moderate to heavy damage either from the air or on the ground.

Chermes can successfully attack only where living tissue is within 1 millimeter of the bark surface 1/. Because of this limitation, which is due to the length of the insects' stylets, stem infestations may be found almost anywhere on trees from seedling to pole size, but are usually well above the ground on mature trees. Combinations of stem and crown attacks often occur. In general, it can be said that trees with stem infestations succumb more rapidly than those that are attacked in the crown only.

1/ One millimeter equals approximately 1/25-inch.

Moderate to heavy infestations may seriously affect growth of individual trees. However, in Pacific silver fir stands now infested most of the trees are mature or overmature; hence growth reduction is not of great significance. So far the only young silver fir affected are in the understory of infested mature stands or immediately adjacent to them. No significant infestations have been found on silver fir that regenerated in clearcuts, although understory trees released by cutting often show evidence of gouting prior to release.

The insect has not shown this preference for mature trees when attacking subalpine or grand fir. On subalpine fir particularly, trees of all sizes are attacked and marked reduction of increment occurs. Researchers in other countries have found that the insect may greatly reduce stand yields. No detailed evaluation of the effect of chermes on tree growth has yet been made in the Northwest.

CONTROL

Natural Control

Temperature plays an important part in regulating chermes life processes such as the hatching of eggs and rate of development. Accordingly, population fluctuations may be affected considerably by seasonal temperature. It does not, however, seem to have a profound effect on mortality. Balch (2) has shown that the insect will survive very low as well as high temperatures. He found that first instar overwintering nymphs will survive temperatures as low as -32° F. while all forms will survive high temperatures if protected from the direct rays of the sun.

Varty (15) reported high mortality of neosistens after prolonged steady rain. Balch (2), however, was unable to show that rainfall had deleterious effects on chermes populations other than to wash some eggs from the trees. Observations in the Northwest indicate that many newly hatched nymphs that are not protected by "wool" are killed by rain. High winds, with or without rain, may also be important in removing eggs and nymphs from the host.

Studies have failed to reveal any significant insect or disease enemies of chermes in the Northwest. Two species of predaceous flies (Leucopis sp. and Neocnemedon sp.) have been found feeding on it in the Mount Hood area, but so far they do not seem to be of great importance. A few fly larvae have also been noted in the Mount St. Helens area, but they have not been identified and their importance has not been evaluated.

Plate IV

BOLE INFESTATION

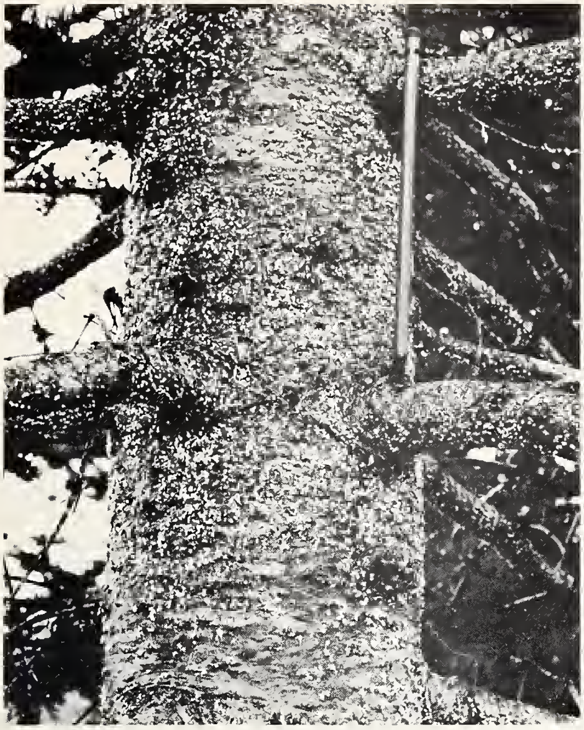


Figure 1. Heavy bole infestation on subalpine fir.

Figure 2. Patches of wool under which adults feed and lay eggs. (x13)

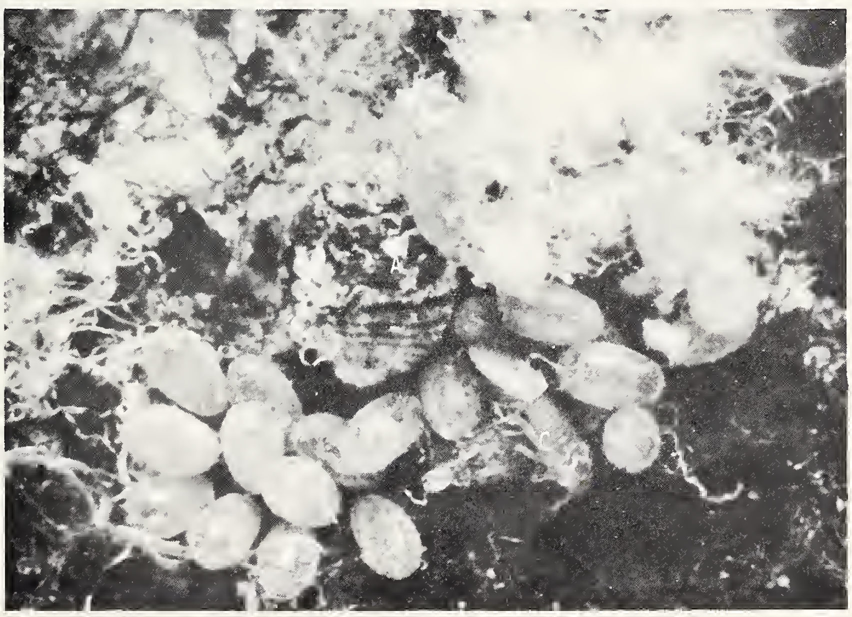


Figure 3. Adult (A); eggs (B); hatching nymph (C). (x45)

In other parts of the world where chermes is destructive, predaceous flies, beetles and mites have been found to effect some control. Between 1933 and 1941, four predators were introduced into eastern Canada from Europe. One fly, Leucopis obscura, became established. This species spread rapidly and by 1947 was present throughout most of the host range but so far has not effected a high degree of control, especially in light infestations (Clark et al (7)). Since 1951 additional liberations of various species of predators have been made; two species of predaceous beetles and one fly have become established. Since 1951 some of the predators introduced into Canada have also been successfully colonized in chermes infestations in the northeastern United States. Plans are being made to import some of these predators to the Northwest.

Characteristics of the host tree appear important in the success or failure of chermes attack. Factors such as bark texture and thickness, time of leafing, rate of growth, ability of the plant to resist damage, and plant antibiotics may have an important effect on the success of attack.

All living tissue from the bark to the wood may be killed by heavy stem attack. In some instances, however, the tree may react to chermes attack by producing a layer of secondary tissue (secondary periderm), which apparently seals off the inner bark, thus protecting the cambium. If this protective layer develops at a depth of more than 1 millimeter below the epidermis, further attacks by chermes are prevented.

Chemical Control

Chemical control in the large old-growth stands of the Northwest is impractical, if not impossible, with present insecticides. The insects are easily killed if miscible oils or other insecticides reach them, but it is impossible with existing aerial spray equipment to get satisfactory application of insecticides on the insects in their many protected locations, under lichens, on the bottom sides of limbs, in bark crevices, etc. Control on small trees has been attained with a six percent miscible oil spray (Keen 8), nicotine sulfate (Balch 2), and certain chlorinated hydrocarbons (Varty 15). In 1955, a fair degree of control in the Wind River Arboretum on small trees was obtained by Forest Service entomologists with a 0.6 percent malathion spray. In the 1930's, test-spraying of infested grand fir in the Willamette Valley with nicotine sulfate was successful.

In addition to the problem of killing the insects, there are many economic and social aspects connected with aerial spraying over forests. Such matters as the effect of the chemicals on wildlife, fish, and man must be carefully investigated before developing control programs.

Silvicultural Control

Because chermes has so recently become an important pest in the Northwest, no research has yet been undertaken here to learn if there are forest practices that can be used to minimize damage. Even in Europe, where studies of A. piceae and A. nusslini have been made for a century or more, only a few preventative methods are advocated. These have met with limited success and are practicable only under very intensive forest management (Varty 15).

In his review of European literature, Rudinsky (12) cites the following precautionary measures used to reduce damage: (1) Refrain from moving infested logs through non-infested stands, (2) take into account prevailing wind direction when establishing cutting boundaries, (3) fall infested trees away from non-infested ones, and (4) clean all logging equipment before moving it to new areas.

Following considerable experimentation in Canada with A. piceae on balsam fir (Abies balsamea (L.) Mill.), Balch (2) recommended that damage can be minimized by short cutting cycles, management on a short rotation, selective cutting, and maintenance of full stocking.

Despite the general lack of success in other countries in using forest management techniques for controlling chermes, investigations should be made in the Northwest to determine the possibilities of control in this region. From observations made so far the following avenues of investigation appear to offer most promise:

1. If noble fir proves to be resistant in this region, it may be possible to use it to replace Pacific silver fir and subalpine fir at high elevations. At lower elevations, Douglas-fir and hemlock may be used as substitutes for silver fir and grand fir.

2. Species of Abies not native to this region should be introduced and tested both for resistance to chermes and for silvicultural suitability. Of some twenty native and exotic species of Abies in the Wind River Arboretum, fifteen of them are so far uninfested. This suggests that other species, genetically resistant strains, or hybrids might be introduced or developed. It is interesting to note that the 20-to 30-year-old Pacific silver fir in the Arboretum are uninfested to date, but subalpine fir of the same age are rapidly being killed.

3. It has been noted that some Pacific silver fir trees in heavily infested stands remain undamaged by chermes. It seems possible that these trees may be chemically or physically resistant. Tests should be made to determine if resistant strains exist and the nature of resistance.

4. In Pacific silver fir, stand age, density, position on slope, and species composition appear to be correlated with the degree of damage by chermes. So far, only mature or overmature stands are significantly attacked, and the heaviest damage is in stands having a high percentage of silver fir. On study plots there appears to be a correlation between tree diameter and degree of damage, with the largest trees hardest hit. This suggests that silver fir might be managed on a short rotation basis without suffering excessive mortality.

5. Infested Pacific silver fir left along cutting lines is suffering especially heavy mortality. Whether this is caused by chermes alone is not known. There appears to be merit, however, in removing all mature silver fir from mixed stands as far back from the cutting edge as logging practice will allow.

6. Where forest management practices permit, it is advisable to selectively log the dead and dying Abies. This should expedite getting over the tremendous area needing salvage treatment, and minimize overcutting of intermingled species.

The above possibilities should be regarded only as suggested approaches to the chermes problem. They have been developed from exploratory field examinations and miscellaneous observations; conclusive recommendations will not be possible until comprehensive testing and research have been done.

WHAT IS BEING DONE ABOUT THE PROBLEM

In the fall of 1956 the Chermes Committee of the Northwest Forest Pest Action Council was organized. This committee is composed of private, state and federal foresters and has as its overall objective the promotion of cooperative action by all forest land managers who are confronted with the chermes problem. Specific objectives of the group are to publicize the problem, to stimulate survey and salvage of the affected timber, and to encourage needed research (10).

Other cooperative action on survey, salvage, and research has been undertaken or is being developed. Details and progress of this work are described in the following section.

Survey and Salvage

Emphasis on the chermes problem to date has been on survey and salvage. Since 1954 the U. S. Forest Service and Weyerhaeuser Timber Company have made periodic aerial and ground surveys to determine the location and intensity of chermes infestations. More intensive surveys have been made of selected areas. These surveys have provided information for initial salvage planning and have shown the general trend of the chermes outbreak.

Considerable salvage of dead and dying Pacific silver fir has already been accomplished in some of the hardest hit areas, where access roads existed or could be quickly built. Long-term cutting budgets and programs have been or are being revised, and plans have been made to allow concentration of manpower and logging equipment in critical areas. As previously mentioned, plans for a major program have been developed by the U. S. Forest Service to salvage the distressed timber on the Gifford Pinchot National Forest. Special funds will be needed to finance this large-scale program of access road construction and timber sale administration. Private companies have adopted similar action programs.

The combination of insufficient roads into many true fir stands, the short operating season at high elevations, and the mixed timber types, all coupled with the necessity of immediate salvage, present the forester and logger with an acute problem. Careful planning of roads and use of the most efficient logging equipment will expedite matters considerably. Some improvement in pattern and efficiency of logging roads have recently been reported (14). Readily portable yarders have been used successfully in various thinning and salvage operations (4). Weyerhaeuser Timber Company is using special portable equipment to selectively log chermes-infested and killed trees. These and other methods that will allow rapid and economical coverage of the problem areas should be considered so that losses through deterioration can be minimized.

Research

Since 1954 entomologists of Weyerhaeuser Timber Company and the Pacific Northwest Forest and Range Experiment Station have been working cooperatively on exploratory studies of the chermes problem. Studies are being made of the biology of the insect, the trend of the outbreak, and methods of measuring mortality.

Biological Studies - Lack of specialists and facilities for studying this very complex insect has meant that biological investigations have been expecially limited in scope. On biological studies, Weyerhaeuser researchers have concentrated their efforts on the insect as found on Pacific silver fir. Their studies are concerned with (1) the life history and habits of the insect, (2) the nature and cause of "gout" formation, and (3) other insect-host relationships.

Biological studies by the Forest Service are concerned with (1) the biology and habits of the insect as found on Pacific silver fir, grand fir, and subalpine fir in various parts of Oregon and Washington; (2) the incidence of chermes attacks on native and exotic species of Abies in the Wind River Arboretum; (3) the distribution of the chermes outbreak in Oregon and Washington; and (4) the abundance and identification of insect predators preying on chermes on various host trees. Although studies by the two organizations have been limited, much has been learned of the general habits of the insect and the nature of damage on different hosts. Findings from biological observations have been described in the preceeding sections of this report.

Studies of Damage Trends - A cooperative study was started by Weyerhaeuser and the Experiment Station in 1954 to determine the rate of decline and mortality of infested trees and stands. The study is being made in Pacific silver fir stands in the southern Washington Cascades. Six plots of 100 tagged trees each were established in 1954 by the two agencies; an additional 12 plots of 50 trees each were established in 1956 by Weyerhaeuser. Objectives of the study are:

1. To determine rate of decline and mortality of trees and stands showing various degrees of infestation.

2. To develop marking guides to assist in establishing cutting priorities for infested trees and stands.

3. To provide volume data on mortality already incurred.

4. To determine yields and deterioration rates of chermes-killed Pacific silver fir.

In addition to their use for recording mortality, the tagged plot trees are examined annually to determine top and branch kill, degree of gouting, foliage color, foliage density, amount of new foliage, presence of chermes, and presence of other insects such as bark beetles. From this examination, an overall rating or condition class is given each tree. A general summary of the initial and current condition of trees on the 6 plots established in 1954 is shown in Tables 1 and 2 1/. As shown in table 1, decline of tree vigor has been quite variable among the six plots.

1/ The 12 plots established in 1956 have not been established long enough to provide significant data.

Mortality on the plots has ranged from 2 to 28 percent of the basal area. A cruise of the stand surrounding the most heavily infested plot (No. 3) showed that 11,000 board feet per acre (gross Scribner scale) were killed from 1955 to 1956 alone. Mortality has been highest among trees in the dominant and co-dominant crown classes, and in trees near exposed edges.

Many trees that were heavily gouted and rated as "seriously weakened" in 1954 have declined slowly over the three years they have been studied (table 2). This is encouraging, because it indicates that the length of time for effective salvage may be longer than originally thought.

Deterioration Studies - Studies will be started in 1957 of trees that have died on the trend plots (13). These data will supplement information obtained from a recent deterioration study of beetle-killed silver fir in northern Washington (17). From that study it was learned that the beetle-killed trees were generally not salvable for lumber manufacture after about 3 years. When the dead trees are used for pulp, salvage is possible for a considerably longer period. An earlier study by Buchanan and Englerth (6) showed that most true firs were beyond use for any purpose 8 years after death. Even after a few years, dead true fir shatters badly when felled. How deterioration rates of chermes-killed trees compare with these earlier findings will be determined by the present study, which is designed to determine pulp and timber yields, breakage when falling killed trees and the identity of the fungi and insects causing deterioration.

Aerial Photograph Studies - An important part of the chermes problem is how to locate and evaluate timber needing salvage. As has been mentioned, aerial sketch maps prepared annually have provided generalized information on the location and degree of damage; they do not however, provide sufficiently detailed information for planning and carrying out salvage. To solve this problem, investigations in the use of aerial color photographs of various scales have been carried on since 1955 by the Experiment Station, Weyerhaeuser Timber Company and the Lands Division of Northern Pacific Railroad. The studies are being conducted in the Mount St. Helens area of Washington.

Table 1.--1956 summary of crown condition on balsam woolly aphid plots 1/

Basis: 100 trees from each of 6 plots.

Plot No.	Ave. DBH of all trees	Ave. DBH of all trees dead or seriously weakened	Total No. of trees by crown class 2/				Dead or seriously weakened trees by crown class								Percent of stand dead or seriously weakened	Ave. numerical condition 3/ of trees by crown class				Ave. numerical condition of all trees at last exam	Ave. numerical condition of trees at initial exam
							No. trees				Percent										
			D	CD	I	S	D	CD	I	S	D	CD	I	S		D	CD	I	S		
1	29.1	35.4	44	23	9	24	24	10	0	5	54.5	43.5	0.0	20.8	39.0	2.4	2.1	1.7	1.2	2.01	1.92
2	26.4	29.8	40	35	23	2	26	14	6	2	65.0	40.0	26.1	100.0	48.0	2.8	2.1	2.0	3.5	2.41	2.37
3	28.0	29.7	67	20	12	1	50	12	5	0	74.6	60.0	41.7	0.0	67.0	2.9	2.5	2.5	2.0	2.81	2.17
4	20.0	23.6	30	42	24	4	11	6	4	1	36.7	14.3	16.7	25.0	22.0	2.1	1.5	1.1	1.2	1.56	1.28
5 4/	18.6	23.8	7	50	39	1	3	7	0	0	42.8	14.0	0.0	0.0	10.3	2.3	1.7	0.9	2.0	1.37	.99
6	23.6	27.1	48	30	22	0	24	8	4	0	50.0	26.7	18.2	0.0	36.0	2.3	1.9	1.6	- -	2.03	1.27
All plots	24.31	29.43	236	200	129	32	138	57	19	8	58.5	28.5	14.7	25.0	37.2	2.55	1.88	1.46	1.39	2.03	1.67

1/ Trees on plots 1, 4, 5, 6 have been examined since 1954; those on plots 2 and 3 since 1955.

2/ Crown classes:
D - Dominant
CD - Co-dominant
I - Intermediate
S - Suppressed

3/ Condition classes:
0 - Full vigor
1 - Slightly weakened by chermes
2 - Moderately " "
3 - Seriously " "
4 - Dead " "

4/ Plot No. 5 has 3 trees missing from wind throw.

Table 2.--Summary of crown condition changes on all plots, 1954-56 1/

Basis: 100 trees from each of 6 plots.

Original crown 1/ condition class	Crown condition change by 1956 2/				
	No change	Decline 1 class	Decline 2 classes	Decline 3 classes	Recovered 1 class
	Percent	Percent	Percent	Percent	Percent
Full vigor	44.4	48.1	7.4		
Slightly weakened	45.1	28.7	14.7	1.4	10.1
Moderately weakened	40.2	40.2	3.0		17.7
Seriously weakened	58.2	37.3			5.5

1/ Trees on plots 1, 4, 5 and 6 have been examined since 1954; those on plots 2 and 3 since 1955.

2/ Crown condition classes used:
0 - Full vigor
1 - Slightly weakened
2 - Moderately weakened
3 - Seriously weakened
4 - Dead

Various scales of panchromatic, color and camouflage-detection films have been tested. Camouflage-detection is a combination of color and infrared emulsions used by the Armed Forces. Results are encouraging, especially with the color and "c-d" films. By interpretation of large-scale photographs (1:3000-1:5000), chermes-killed and damaged trees can be plotted and counted with reasonable accuracy. Present indications are that valid estimates of volume can also be made by aerial photographic sampling combined with ground checking. If a survey method of this kind can be developed, time and money will be saved, and salvage greatly expedited. In view of this urgent need, further testing of photographic procedures will be done by the Pacific Northwest Forest and Range Experiment Station in 1957.

CONCLUSIONS AND RECOMMENDED ACTION

The balsam woolly aphid has already killed very large volumes of timber and threatens the true fir stands of Oregon and Washington. The immediate problem of the forest industry is what to do about the thousands of acres of killed or damaged Pacific silver fir sawtimber that currently or within the near future should be salvaged. There are several factors affecting a solution to the problem, with the following being perhaps the most important:

1. Most of the tremendous volume of distressed timber is in high elevation areas undeveloped by timber access roads.

2. Mills can presently utilize only a limited amount of true fir in their manufacture of forest products.

3. Ownership of forest land in much of the affected area is of a checkerboard nature.

Aggressive salvage programs have been started in the affected silver fir stands but need to be greatly accelerated and expanded by all owners. The program should be guided by the rate of kill and deterioration, and should attempt to hit the heaviest concentrations of damage first. Efforts should be made to develop new uses for true fir; trade promotion by the forest industry offers a means of developing such uses. The problems created by checkerboard land ownership can be solved only by prompt cooperative action of private, state and federal owners. The entire salvage program should be regarded as an emergency measure and pushed accordingly.

The chermes problem in subalpine fir and grand fir is of a different nature. The infestation in subalpine fir is severe in terms of area and numbers of trees killed, but timber values are relatively low. Watershed and recreation values, however, are high and an early evaluation of the effects of loss of trees on these areas is needed. Outbreaks to date in grand fir are few and scattered, and although significant locally, are not considered important regionally at this time.

The chermes outbreak has created numerous problems for public and private forest managers. Long term management plans must be changed. The departure from a planned harvest program will exceed the sustained yield annual cut in many areas, create added fire hazards, and will require additional personnel to administer and do the salvage job. The problem of what tree species to encourage in the next crop is also an important one. Many of these problems are the direct responsibility of the forest manager; others are logically the responsibility of research.

Much more research is needed, with the following studies regarded as being most urgent:

1. Studies to develop survey techniques for evaluating mortality as to location, amount, time of death, merchantability, etc.

2. Studies to determine how long attacked trees live and how long killed trees remain merchantable.

3. Studies to determine the habits and life histories of chermes affecting various host trees in Oregon and Washington.

4. Studies to develop control measures. Biological control appears to offer considerable promise and should receive high priority; chemical control and indirect control through forest management should also be investigated.

5. Studies to determine the relationships between the insects and the host trees. Investigations are needed to determine host preferences, host resistance, and physiological effects upon trees.

6. Silvicultural studies of *Abies* to determine what tree and stand characters increase susceptibility to chermes outbreaks. Genetics studies to develop resistant trees through selection, breeding and propagation should also be undertaken.

Research on the problem will be continued and expanded in 1957 by entomologists and other research specialists of Weyerhaeuser Timber Company and the Pacific Northwest Forest and Range Experiment Station. Additional personnel and facilities are being added to both organizations to provide increased effort on the investigative program. It is felt that the only lasting solution to the chermes problem must be developed from a basic understanding of the insect and its hosts.

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